B. C. Loughman et al. (Eds.), Structural and functional aspects of transport in roots, 219–222.
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Quantification of air-filled root porosity: A comparison of two methods

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Key words: anaerobiosis, aerenchyma, methods root research, pycnometer, *Zea mays*

Introduction

Air-filled porosity of the root cortex is important for aeration of roots in situations where the external oxygen is insufficient. A quantitative theory predicting the depth a vertically growing root can penetrate into the soil is now available for simultaneous internal and external oxygen transport as a function of the air-filled porosities of soil and root (De Willigen and Van Noordwijk, 1987). Maximum depth of root penetration in the soil depends on root diameter, respiration rate, conductance of root epidermis-plus-exodermis for oxygen and air-filled porosity of both soil and root. Reliable methods for quantification of the air-filled porosity of roots or root segments are needed for practical applications of this theory. Two measurement techniques will be discussed here, direct measurements on microscopic sections and the pycnometer method as described by Jensen *et al.* (1969). To obtain root material with significant variation in porosity, maize plants were grown with and without aeration, including some factors stimulating or reducing the normal formation of air spaces via ethylene (Konings, 1983).

Materials and methods

Plant material

Maize plants were grown on a nutrient solution in a growth chamber (temperature 22°C, relative humidity about 40%) on a full-strength nutrient solution, replaced once a week; 3 plants were grown per 5-l pot from 2 weeks after sowing onwards. To obtain low root porosities, $AgNO_3$ was added to reduce ethylene formation; to obtain high porosities a low nitrogen supply was used in the presence of the ethylene precursor ACC (1-aminocyclopropane-1-carboxylic acid). Following Konings (1983), four treatments were used, each in two variants: AA. Aerated, with $AgNO_3$ (10^{-6} *M*), A. Aerated, N. Nonaerated, NN. Nonaerated, with ACC (10^{-5} *M*), low N-supply (3.4 instead of 10.2 me l^{-1}) during pretreatment and without N in the last week before harvest.

In variant 1 the pretreatments were implemented at the start of the solution culture period; in variant 2 treatments were only implemented in the last week before the harvest and the plants were aerated in a full-strength nutrient solution beforehand. Plants were harvested 11 weeks after sowing. All treatments were in duplicate.

Measurements on microscopic sections

The surface area of root pores in microscopic sections was calculated from visual estimates (calibrated with computer measurements) of the part of the cortex tissue occupied by air spaces and from measured diameters of stele, cortex and exodermis-plus-epidermis. Photographs of selected sections were compared by Dr H Konings with his quantitative results.

Pycnometer measurements

The pycnometer method is based on a comparison of the density of intact root tissue, including air-filled pores, and that of root homogenate without air. Intact root samples (1 to 3 g fresh weight) are carefully cut into pieces of 5 cm length directly before they are placed in a pycnometer